RPRP-S0003

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ADVANCED ELECTRIC POWER



# Integrated Gasification Combined Cycle Technology

Strategic Objective

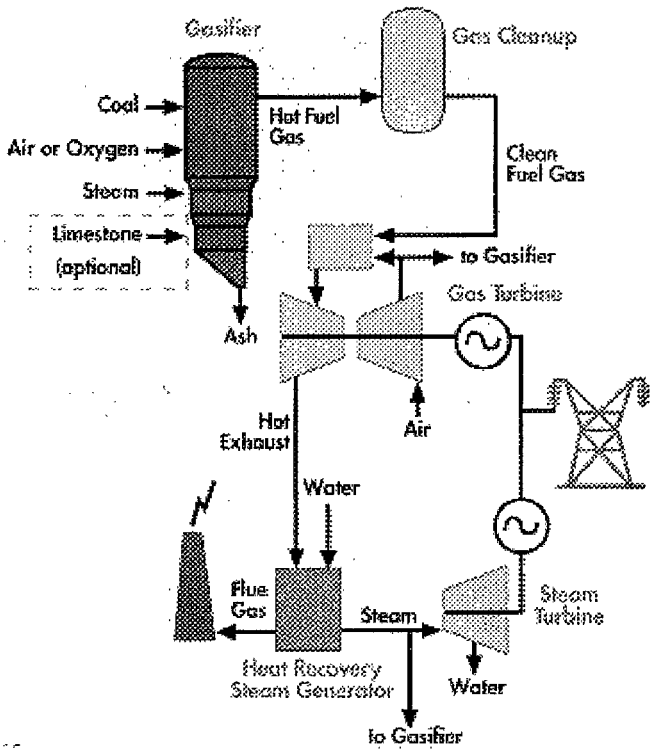
Key Projects

Link to Field Data

Integrated Gasification Combined Cycle (IGCC) systems replace the traditional coal combustor with a gasifier and gas turbine. Over 99 percent of the coal's sulfur can be removed before the gas is burned in the gas turbine. Exhaust heat from the gas turbine is used to produce steam for a conventional steam turbine. The gas and steam turbines operate together as a combined cycle.

First-generation IGCC power systems capable of achieving efficiencies up to 42 percent are now at the commercial demonstration stage of development. Advanced IGCC systems demonstrated in the late 1990s will lead to commercial offerings with efficiencies of 45 percent. Technology advances such as gas turbine developments will result in further improvements, pushing system efficiencies beyond 50 percent.

## How IGCC Works




*Integrated Gasification Combined Cycle Schematic Diagram*

IGCC systems are extremely clean, and much more efficient than traditional coal-fired systems. The technology is based on an advanced coal utilization technology - a coal gasifier used in place of the traditional coal combustor - coupled with a key enabling technology, the advanced

gas turbine. The resulting system is an integrated gasification combined-cycle configuration that provides high system efficiencies and ultra-low pollution levels.

In an IGCC system, coal is converted into a gaseous fuel, which, when cleaned, is comparable to natural gas. At least 99 percent of the coal's sulfur is removed from the coal by converting it into this gaseous form in an advanced gasifier before combustion. The hot gas is further cleaned by an advanced cleanup process before being burned in the gas turbine to generate electricity. exhaust heat from the gas turbine is used to produce steam for a conventional steam turbine, resulting in the two cycles of electric power generation.

The IGCC systems that are currently available commercially have demonstrated exceptional environmental performance. Unparalleled success has been shown in sulfur dioxide (SO2) removal, nitrogen oxides (NOx) reduction, and particulate removal. The result? SO2 and NOx emissions are less than one-tenth of that allowed by New Source Performance Standards limits.

At the same time, IGCC efficiency levels top 40 percent. The efficiency level of a power plant is measured by the amount of electrical energy produced per amount of coal energy used to create it, and The baseline efficiency of a conventional coal-fired plant is at best 34 percent. From 1950 until today, conventional power plants have managed to increase efficiency slowly from 25 percent to this level. IGCC offers a step up in efficiency improvement.

- **45 PERCENT EFFICIENCY**

  More advanced IGCC systems target efficiency levels of up to 45 percent and lower capital costs by the year 2000. Improvements in hot gas desulfurization and hot gas particulate removal will be responsible for lowering capital costs by that time to only $1,200 per kilowatt. These systems will differ from those commercially available in that they may use hot gas cleanup at 800-1,200 degrees F, with air-blown gasifiers operating at 1,800 degrees F. The lower capital costs and increased efficiencies will lower the cost of electricity.

- **52 PERCENT EFFICIENCY**

  IGCC systems based on advances in gas turbine technology will demonstrate net system efficiencies of 52 percent by the next decade's end. System improvements developed by DOE's Advanced Turbine Systems (ATS) program will be adapted to coal gas, and by 2010, these ATS-based systems will result in even lower capital costs, at $1,050 per kilowatt.

- **FUTURE DEVELOPMENTS**

  The full potential of IGCC will be realized through focused research and development aimed at achieving continuous product improvement. In addition to development of the major components of the technology, advanced research is also being conducted in other areas of product enhancement. looking ahead, further improvements will occur during widespread commercial use. The commitment by DOE to such IGCC development is long-term,

since it is clear that it offers the road to cheaper, cleaner electricity for the American people.

The road to affordable clean electricity also involves commercial commitment to IGCC. This road is built upon an interactive RD?D partnership between government and industry and the way to go is clear.

## The IGCC Advantage

IGCC technology brings many advantages to an energy-hungry but cost-conscious world:

- **A CLEAN ENVIRONMENT.** IGCC can meet all future environmental permitting constraints for the generation of electric power. In an IGCC system, 99 percent of the coal's sulfur is removed before combustion, NOx is reduced by over 90 percent, and CO2 is cut by 35 percent. This environmental performance matches or exceeds that of alternate energy sources.

- **HIGH EFFICIENCY.** The efficiencies that will be achieved by IGCC over the next two decades, ranging from 42 to 52 percent, contrast favorably with efficiencies of at best 34 percent offered by existing coal plants with installed flue gas desulfurization capabilities.

- **LOW-COST ELECTRICITY.** IGCC offers low cost of electricity. The cost of IGCC-generated electricity is now competitive with the cost of electricity produced by a conventional pulverized coal plant, and by 2010 it will drop to 75 percent of this cost.

- **LOW CAPITAL COSTS.** The IGCC plant is cost-competitive to build, at a plant construction cost of $1,500 per kilowatt right now, and $1,050 per kilowatt by 2010. Costs will drop further in subsequent years.

- **REPOWERING OF EXISTING PLANTS.** The components of the IGCC system can be integrated into an existing system in modular form, allowing a user to take advantage of an existing site and its steam-generating equipment. Staged additions can be made in blocks to match one or more steam generators, and will give the resulting system two-and-a-half times the generating capacity.

- **MODULARITY.** The modular nature of IGCC plant systems allows for staged additions in blocks ranging in size from 100 to 450 megawatts. As advanced turbine systems evolve, the capacity of single units will increase, and the trend will be to add large-capacity modules.

- **FUEL FLEXIBILITY.** The combined-cycle portion of an IGCC plant can be fueled by natural gas, oil, or coal. This means not only that a plant can switch to coal from natural gas as gas becomes unavailable or unacceptably expensive, but also that an IGCC plant can be fueled by natural gas or oil in case of unplanned events such as disruption in fuel supply. In addition, most gasifier systems can be easily adapted to different coals.

- **PHASED CONSTRUCTION.** IGCC systems are unique in the

economical way in which they meet the demands of utility growth patterns. A first-phase installation might include only a gas turbine, operating as a simple natural-gas-fired cycle and providing about two-thirds of the plant's ultimate capacity. Addition of a steam turbine would create a combined cycle with full capacity. A third phase of installation would integrate the gasifier and gas cleanup systems when justified by low coal prices, lack of gas availability, or need for conversion to baseload capacity.

- **LOW WATER USE.** The water required to operate an IGCC plant is only 50 to 70 percent of the quantity required to run a pulverized coal plant with a flue gas desulfurization system.

- **LOW CO2 EMISSIONS.**IGCC systems offer significant reductions in CO2 emissions per unit of power produced, because their higher efficiency means that less coal must be burnt to produce each unit. When combined with the fuel cell systems of the future, IGCC technology will be able to further reduce CO2 emissions per unit of electricity .

- **CONTINUOUS PRODUCT IMPROVEMENT.** The IGCC system is composed of several major elements that are the subject of ongoing advanced research and development. This development follows a planned progression toward ever more efficient performance by the technology.

- **REUSABLE SORBENTS.** Reusable process media remove sulfur from the coal-derived gas prior to combustion in the gas turbine. By contrast, Rue gas desulfurization of pulverized-coal and fluidized-bed power plants uses limestone, dolomite, or other sulfur sorbents that require disposal.

- **MARKETABLE BY-PRODUCTS.** Waste disposal is minimal at an IGCC plant. The sulfuric acid or elemental sulfur that is produced is a marketable product. Ash and any trace elements are melted, and when cooled, become an environmentally safe, glass-like slag that can be used in the construction or cement industries.

- **CO-PRODUCTS.** In addition to producing electricity, the coal gasification process can be diverted to co-produce such products as fuels in the form of methanol or gasoline, urea for fertilizer, hot metal for steel making, and chemicals.

- **DEMONSTRATED SUCCESS.** The IGCC system is being demonstrated fully by multiple projects under way that not only foster competition and rapid product improvement, but also show conclusively how successfully the system operates and how it can be maintained. A full range of variations of the IGCC process will be demonstrated: several different gasifiers, cleanup systems, repowering applications, and coals, and combinations of such elements.

- **PUBLIC ACCEPTABILITY.** IGCC sites offer an acceptable electric power generation option to a public concerned about environmental hazards and waste. Negligible plant emissions, little or no waste, safe jobs for workers, safe environments for their families, low-cost electricity for their homes, and job security based

on a dependable demand for the plant's product are factors that result in acceptance by the general public.

## Achieving the Vision

An IGCC power system currently produces electricity efficiently and cleanly, with only one-tenth of the emissions allowable by Federal regulations. IGCC engineers have solved many of the problems posed by traditional coal combustion. Now the challenge is to reduce the costs of building or converting plants to use IGCC.

The current capital cost of building an IGCC power plant is as low as $1,500 per kilowatt. Following planned commercial-scale demonstration projects, This cost is expected to drop to $1,200 per kilowatt by the end of The century, and it is estimated that it will drop further, to $1,050, by 2010, 75 percent of the cost of electricity from one of today's conventional power plants.

How do we get to this point?

## Improving the Key Components

The carefully planned development path of IGCC plots its course around a number of building-block technologies, many of which are of joint value for other advanced power generation products. These development projects include components and subsystems.

Four major areas of technology contribute to successful IGCC development:

- Advanced Gasifier Systems
- Hot Gas Desulfurization
- Hot Gas Particulate Removal
- Advanced Turbine Systems.

**ADVANCED GASIFIER SYSTEMS.**
The costs associated with the gasifier subsystem account for about a quarter of the cost of electricity produced by an IGCC plant. With an eye, therefore, to reducing capital costs and achieving higher efficiency, DOE funded R?D of five different advanced gasifier concepts during recent years. Another gasifier options is now under development: an advanced transport reactor concept that will provide gas for testing of hot gas particulate removal devices at the Energy Department's showcase Power Systems Development Facility.

**HOT GAS DESULFURIZATION.**
Studies are being undertaken to determine the optimal hot gas cleanup temperature that will provide the lowest cost of electricity. Sulfur removal operations between 800 degrees F and 1,200 degrees F, using low-cost, long-life sorbents, are being explored in moving-bed, fluidized-bed, and transport-bed configurations.

**HOT GAS PARTICULATE REMOVAL.**
Over a dozen particulate removal systems with wide-ranging features are

being studied. Components such as filter elements and system design are being developed rapidly as dust characteristics are better understood, and as advanced materials such as composites are being applied. Three particulate removal devices were selected for hot coal gas testing at the Power Systems Development Facility.

**ADVANCED TURBINE SYSTEMS (ATS).**
The ATS effort is one of DOE's highest priority initiatives. The Department has set a goal of commercial demonstration of a natural gas, combined-cycle, over-60-percent-efficient power plant by 2000. Such a system will have 10 percent lower emissions than today's best power plant, will offer a 10 percent cost reduction, and will be coal-gas adaptable. The boost in efficiency levels added to electric power plants by the advanced turbine system plays a major role in enabling IGCC to meet its vision for the year 2010

## IGCC In Action

## IGCC Demonstration Projects

- **WABASH RIVER COAL GASIFICATION REPOWERING PROJECT.** PSI Energy and Destec Energy have joined forces in Indiana to upgrade an existing plant using advanced IGCC gasifier technology. The joint venture, part of DOE's Clean Coal Technology Program, has repowered one of six units at PSI's Wabash River plant with a 262-megawatt system. The project, funded 50 percent by DOE, is demonstrating Destec's oxygen-blown, two-stage entrained-flow gasifier with hot particulate cleanup, which produces a medium-Btu syngas from high-sulfur bituminous coal.

- **PI?ON PINE IGCC POWER PROJECT.** In Reno, Nevada, Sierra Pacific has chosen to install an IGCC system to meet anticipated load growth, citing the technology's advantages of flexibility, diversity, and reliability. General Electric's gas turbine and KRW's air-blown fluidized-bed gasifier will be used, with hot gas cleanup using an in-bed sulfur capture process, ceramic filters, and external desulfurization. The plant will process low-sulfur western coal. The Nevada utility and DOE are sharing the costs of the project, which was initiated in 1992.

- **TAMPA ELECTRIC COMPANY IGCC PROJECT.** Tampa Electric in Lakeland, Florida, is building a 250-megawatt IGCC facility as part of a major expansion over the next decade. The system will consist of Texaco's oxygen-blown gasification technology, paired up with General Electric's power generation equipment. It will also incorporate an innovative hot gas cleaning system. The plant will process 2,300 tons per day of bituminous coal, using a moving-bed desulfurizer, integrated air separation, and parallel hot and cold gas cleanup.

**Dedicated Department of Energy Research Facilities**

Three large-scale R?D facilities have been set up to focus on research supporting commercial market entry of IGCC systems. These facilities explore and demonstrate system integration of hot gas desulfurization, component scale-up of particulate control devices, and gasifier product

improvement.

- **POWER SYSTEMS DEVELOPMENT FACILITY.** Southern Company Services will operate this showcase multi-module test center in Wilsonville, Alabama, integrating power systems components, including hot gas particulate control devices, and evaluating their performance using fuel gas produced by a 38-ton-per-day transport gasifier.

- **HOT GAS CLEANUP PILOT PLANT.** This $22-million test program in Schenectady, New York, is providing data on a moving-bed hot gas desulfurizer system with fuel gas produced by a fixed-bed gasifier.

- **FETC HOT GAS DESULFURIZATION PROCESS DEVELOPMENT UNIT.** In Morgantown, West Virginia, a $10-million Process Development Unit will test a hot gas fluidized-bed and/or transport-bed desulfurization process, fueled by a 150,000-standard-cubic-foot-per-hour syngas generator.

## The IGCC Opportunity

With the advent of advanced power generation technologies like IGCC, coal is projected to remain the most economical, long-term fuel of choice for electricity production. Because of its low cost and the resulting low cost of electricity to customers, coal will be used more and more widely throughout the world as an energy source. Already the prices of coal and electricity have, in real terms, declined throughout the 1980s.

When efficiency, cost-of-electricity, and environmental benefits are compared, IGCC technology scores higher than many other advanced technologies that will be available to meet the energy needs of the next several decades, and it is likely that IGCC will be one of the most attractive power generation technologies for the 21st century. Because of potential IGCC improvements that will lower the cost of producing electricity, it is estimated that the IGCC market share in the United States will increase continually to as much as 30 percent of electricity generation by the middle of the next century, resulting in 450,000 megawatts of capacity.

Outside the United States, the clean coal technology market is projected to climb as high as $870 billion through the year 2010, and the potential market for U.S. exporters is calculated to be about $257 billion. Of this, it is estimated that $215 billion will be available for new applications such as IGCC systems.

Even the most conservative estimates, giving U.S. technology only a 30 percent share of the export market, and IGCC 10 percent of this, the benefits to the United States amount to a $5 billion market opportunity and the creation of 35,000 U.S. jobs (person/year).

All of this adds up to an ultra-clean, super-efficient, low-cost technology that brings strong, calculable benefits to the Nation as a whole as well as to those who invest in it as a private enterprise.

Electricity plays an essential role in U.S. and global economics, and coal is the chief resource worldwide for electricity generation. Only by the use of clean coal power generation technologies like IGCC can we meet the

world's demand for clean, affordable electricity-given the extensive coal reserves worldwide, we can do it at low cost.

## Additional Online Information

DOE's Integrated Gasification Combined Cycle R?D Program is managed by the Federal Energy Technology Center (FETC). This link will take you to the Integrated Gasification Combined Cycle section of the FETC Home Page.

## For More Information:

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